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Abstract

Background

The fitness of Canadian children and youth has not been measured in more than two decades, a period during which childhood obesity and sedentary behaviours have increased. This paper provides up-to-date estimates of the fitness of Canadians aged 6 to 19 years.

Data and methods

Data are from the 2007-2009 Canadian Health Measures Survey (CHMS), the most comprehensive direct health measures survey ever conducted on a nationally representative sample of Canadians. Descriptive statistics for indicators of body composition, aerobic fitness and musculoskeletal fitness are provided by sex and age group, and comparisons are made with the 1981 Canada Fitness Survey (CFS).

Results

Fitness levels of children and youth have declined significantly and meaningfully since 1981, regardless of age or sex. Significant sex differences exist for most fitness measures. Fitness levels change substantially between ages 6 and 19 years. Youth aged 15 to 19 years generally have better aerobic fitness and body composition indicators than 20- to 39-year-olds.

Interpretation

This decline in fitness may result in accelerated chronic disease development, higher health care costs, and loss of future productivity.

Keywords

adiposity, aerobic fitness, anthropometry, body composition, cardiorespiratory fitness, flexibility, muscular endurance, musculoskeletal fitness, obesity, physical fitness, strength

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Childhood obesity and inactivity have been at the forefront of child health concerns in Canada in recent years,[1-5] with compelling evidence that childhood obesity is rising[6-8] and inactivity levels are high.[2,3,9] These trends are particularly important given the strength of the evidence demonstrating the health consequences of childhood obesity[4,5,10] and the benefits of physical activity to childhood health and wellness.[2,3,11-15]

Evidence also indicates that childhood aerobic fitness levels are declining worldwide,[16] that aerobic fitness is related to health in children in a dose-response fashion,[17] and that these relationships are independent of physical activity.[18] Overwhelming evidence demonstrates that higher or improved fitness, including measures of body composition (for example, body mass index, waist circumference, skinfolds), cardiorespiratory function (for example, aerobic fitness) and musculoskeletal fitness (for example, strength, muscular endurance, flexibility), is associated with improved health in children and youth.[11-13,17,18]

The importance of measuring and monitoring the fitness of children and youth is obvious but logistically challenging, and rarely done on large, representative national samples. Notable studies in Canada include the 1972 Nutrition Canada Survey,[19] the 1978 Canada Health Survey,[20] the 1981 Canada Fitness Survey (CFS)[21] and the 1988 Campbell's Survey on the Well-being of Canadians,[22] with the latter two providing the most comprehensive and recent data.

Fitness has not been measured at the national level in more than two decades in Canada. In 2007, in partnership with Health Canada and the Public Health Agency of Canada, Statistics Canada launched the Canadian Health Measures Survey (CHMS) to address this (and other) data gap(s).[23-27] The CHMS is the most comprehensive direct health measures survey ever conducted in Canada. In addition to a detailed health interview, the CHMS includes direct

measurement of indicators of, and risk factors for, chronic disease, infectious disease, environmental exposures, nutritional status, physical activity and physical fitness.[23-27]

Using data from the CHMS, this paper provides an up-to-date overview of the fitness levels of Canadian children and youth aged 6 to 19 years, including estimates of body composition (body mass index, waist circumference, waist-to-hip ratio and skinfolds), aerobic fitness and musculoskeletal fitness (including muscular strength, endurance and flexibility). Where possible, CHMS results are compared with findings from the 1981 CFS[21] to examine temporal changes in fitness.

Methods

Data sources

The Canadian Health Measures Survey covers the Canadian population aged 6 to 79 years living in private households at the time of the survey. Residents of Indian Reserves or Crown lands, institutions and certain remote regions, and full-time members of the Canadian Forces are excluded. Approximately 97% of Canadians are represented.

Ethics approval to conduct the survey was obtained from Health Canada's Research Ethics Board.[26] Informed written consent was obtained from respondents aged 14 years or older. For younger children, a parent or legal guardian provided written consent, in addition to written assent from the child. Participation was voluntary; respondents could opt out of any part of the survey at any time.

Data were collected at 15 sites across Canada from March 2007 through February 2009. Of the households selected, the response rate was 69.6%, meaning that in 69.6% of the selected households, a resident provided the sex and date of birth of all household members. Within each responding household, one or two members were chosen to participate in the CHMS; 88.5% of selected 6- to 19-year-olds completed the household questionnaire, and 86.9% of those who completed the questionnaire participated in the subsequent examination centre component. The final response rate for 6- to 19-year-olds, after adjusting for the sampling strategy,[27] was 53.5%. This article is based on 2,087 examination centre participants aged 6 to 19 years.

Historical estimates of fitness measures are based on data from the 1981 Canada Fitness Survey (CFS), a nationally representative sample of the Canadian population,[21,28,29] initiated and funded by Fitness Canada. The sample was designed by Statistics Canada, using the Labour Force Survey sampling frame. The CFS sample consisted of 13,500 households, 88% of which agreed to participate, meaning that basic demographic information was collected for all household members, and a household member agreed to a follow-up visit when all members would be at home. In these responding households, 30,652 people aged 7 years or older were eligible to participate in the CFS. The CFS had two components: a questionnaire on health and lifestyle (administered to household members aged 10 years or older) and a physical measures component (for respondents aged 7 to 69 years). A respondent to the CFS was defined as a household member who completed the questionnaire and/or participated in the physical measures component. In total, 23,400 household members (76%) responded. Therefore, the overall response rate to the CFS was 67% (88% x 76%). Among CFS respondents who were eligible for the physical measures component, 73% participated, yielding a response rate of 49% to this component (88% x 76% x 73%). The CFS estimates in this article are based on 5,116 respondents aged 7 to 19 years. Fitness testing and anthropometric measures were taken in sampled households between February and July 1981, using standardized equipment and procedures. Testing was performed by university graduates who had degrees in physical education and recreation and additional qualifications in fitness appraisal.

Measures

In addition to a comprehensive health interview conducted in the home, CHMS respondents underwent body composition measurements and participated in directly measured fitness tests in a mobile examination centre.[25]

Most of the measurement protocols for assessing body composition, aerobic fitness and musculoskeletal fitness were taken from the Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA).[30] A detailed description of the specific collection procedures can be found in the *CHMS Data Users' Guide*.[31] The CPAFLA assigns "health benefit ratings" for individual and aggregate fitness measures.[30] These ratings are available only for ages 15 to 69 years and reflect changes expected with age.

The fitness tests and anthropometric measures in the CHMS were conducted by specialists with a degree in kinesiology and certification from the Canadian Society for Exercise Physiology (www.csep.ca) as either Certified Exercise Physiologists or Certified Personal Trainers. Before undergoing any clinic tests, respondents were interviewed to ensure that they were physically able to perform the tests for which they were eligible. They were asked about their physical and health conditions and their use of prescription medications. A Physical Activity Readiness Questionnaire (http://www.csep.ca/CMFiles/publications/parq/par-q.pdf) was completed and signed by all respondents (and by the guardian if the respondent was younger than 14 years). To ensure their safety, respondents were screened out of certain tests, depending on the answers they provided to the screening questions. They were requested to adhere to pre-testing guidelines about food, alcohol, caffeine, nicotine, exercise and blood donations. Detailed information about screening questions, pre-testing guidelines and test eligibility criteria can be found in the

CHMS Clinic Questionnaire[32] and *Data Users' Guide*.[31]

The anthropometric measures collected included height, weight, waist circumference, hip circumference and skinfold measurements. Height was measured using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, USA), and weight was taken with a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada). Waist circumference was measured with a Gulick measuring tape (Fitness Mart, Gay Mills, USA) following the World Health Organization (WHO) protocol[33] (mid-point between last floating rib and top of the iliac crest in mid-axillary line), and hip circumference was measured following the Canadian Standardized Test of Fitness (CSTF) protocol[34] at the level of the symphysis pubis and the greatest gluteal protuberance. The skinfolds were measured using Harpenden skinfold calipers (Baty International, UK) at five sites: triceps, biceps, subscapular, iliac crest and calf.[30] Body mass index (BMI), waist-to-hip ratio, and the sum of the five skinfolds were calculated according to standard procedures.[30,34]

Body composition ratings were derived from the anthropometric measures. Based on BMI, 18- to 19-year-olds were classified as underweight (less than 18.5 kg/m^2), normal weight (18.5 to 24.9 kg/m^2), overweight (25 to 29.9 kg/m^2), or obese (30 kg/m^2 or more).[35] Children aged 6 to 17 years were classified as being normal weight, overweight or obese based on definitions proposed by the International Obesity Task Force.[36] Based on their waist circumference, respondents aged 15 years or older were classified as having a low (less than 80 cm in females; less than 94 cm in males), increased (80 to 87 cm in females; 94 to 101 cm in males) or high (more than 87 cm in females; more than 101 cm in males) health risk.[30,37-39] Finally, an overall body composition health rating was assessed for respondents aged 15 years or older, based on an aggregation of BMI, waist circumference and the sum of five skinfolds, as defined in the CPAFLA.[30]

Aerobic fitness was measured using the modified Canadian Aerobic Fitness Test (mCAFT), during which respondents had to complete one or more three-minute "stepping" stages (up and down steps with increasing intensity) at predetermined speeds, based on their age and sex.[30] Children aged 6 to 14 years started at what is Stage 5 for women, to a maximum of 3 stages. Respondents' heart rate was recorded after each stage, and the test was completed when it reached 85% of their age-predicted maximal heart rate (220 – age). Heart rate was measured with a Polar (Polar Electro Canada Inc., Lachine, Canada) heart rate monitor, or in the case of inadequate signal from the monitor, by auscultation/palpation. Predicted maximal aerobic power (VO_2max) was determined for all participants.[30,40,41] Respondents who completed at least one stage, but stopped midway through a subsequent stage ("partials"), were assigned a score based on their last fully completed stage. "Partials" were usually due to respondents' inability to maintain the cadence of the stepping test, which was particularly evident among younger children. Those unable to fully complete even one stage were coded as "not stated" and were not assigned an aerobic fitness score.

Muscular strength was assessed by measuring grip strength with a Smedley III hand-grip dynamometer (Takei Scientific Instruments, Japan) twice on each hand (alternating) and combining the maximum score for each hand (in kg). Muscular endurance was measured with the partial curl-up test, which required respondents to perform as many partial curl-ups as possible in one minute, at a set pace, to a maximum of 25. Flexibility was assessed with the sit-and-reach test, for which respondents sat on a mat on the floor with their legs extended against a flexometer (a device to measure the distance of a stretch) (Fit Systems Inc., Calgary, Canada); the best of two attempts to stretch as far forward as possible without bending the knees was recorded to the nearest 0.1 cm.

Youth aged 15 to 19 years were assigned "health benefit ratings" of excellent, very good, good, fair, or needs improvement based on their score for each fitness test (aerobic fitness, flexibility, muscular endurance, and muscular strength), their sex and their age, according to definitions specified in the CPAFLA.[30] An overall musculoskeletal fitness health benefit rating was assessed based on the results of the grip strength, partial curl-up and sit-and-reach tests. A back fitness health benefit rating was calculated based on waist circumference and the partial curl-ups and sit-and-reach tests.[30]

The 1981 CFS measured grip strength, sit-and-reach and body composition following collection protocols[21] very similar to those of the CHMS.

Analytical techniques

Data were analyzed separately by sex for three age groups: 6 to 10, 11 to 14, and 15 to 19 years. Estimates of means, standard deviations and medians were produced for all fitness measures (body composition measurements and fitness test scores). Estimates of the means and medians were similar for most measures, although in some cases, means were marginally higher, reflecting somewhat positively skewed distributions. An exception was the bimodal distribution of the number of partial curl-ups completed in one minute (to a maximum of 25), with large percentages of respondents completing either none or 25. As a result, percentage distributions are presented for this measure. Estimates of aerobic fitness from the mCAFT and the partial curl-ups do not include 6- and 7-year-olds, who often could not perform these tests for reasons unrelated to fitness (for example, lacking the co-ordination to follow the cadence). The equation used to predict maximal aerobic power (VO_2 max) is applicable to people aged 15 to 69 years.[30,40,41] In this article, the equation was also applied to 8- to 14-year-olds. Graphs of medians were produced by single year of age, but separate graph lines are presented for those aged 8 to 14 years

and 15 to 19 years to highlight the fact that the equation has not been validated for the younger children (Figure 1).

For the health benefits ratings, percentage distributions are presented. The health benefits ratings used in the analyses apply only to those aged 15 years or older;[30] to provide context, ratings are compared with those for 20- to 39-year-olds (n = 1,185).[42]

Comparisons with the 1981 CFS were made for estimates of grip strength, sit-and-reach, and all body composition measurements. For muscular endurance, comparisons could not be made because the partial curl-up test, which was used to assess this component of fitness in the CHMS, was administered as speed sit-ups in the CFS. And although the same testing modality was used to assess aerobic fitness in the two surveys, small differences in the protocols negated a simple temporal comparison. Additional analyses, which are beyond the scope of this study, will be conducted in future research to fully understand the impact of these differences.

As in the CHMS, CFS respondents were interviewed before undergoing any fitness tests to ensure that they were physically able to perform them. The CFS used screen-out procedures similar to those used for the mCAFT for the CHMS.[31] Therefore, for comparisons of estimates of grip strength and sit-and-reach between the two surveys, respondents who were screened-out of the mCAFT were excluded from CHMS estimates. Because of the potential for changes over time in the age distribution within the three age groups considered, the 1981 estimates were recalculated to standardize to the CHMS population. However, in all cases, the crude and age-standardized estimates for means were similar, so only crude estimates are presented in this study.

The fitness profiles of a typical 12-year-old boy and girl in 1981 and in 2007-2009 are compared. Age 12 was chosen because it is the midpoint of the 6 to 19 year age range examined in this paper. To ensure adequate sample sizes, estimates are based on median values for children aged 11 to 13 years. The silhouettes used to illustrate the comparisons in Figure 3 are not sized to scale.

To account for the survey design effects of the CHMS, standard errors, coefficients of variation and 95% confidence intervals were estimated using the bootstrap technique.[43,44] Estimates of sampling error for the CFS are based on formulae for simple random sampling with the incorporation of a design effect of 1.5 to account for the complex survey design. Differences between estimates were tested for statistical significance, which was established at the level of $p<0.05$.

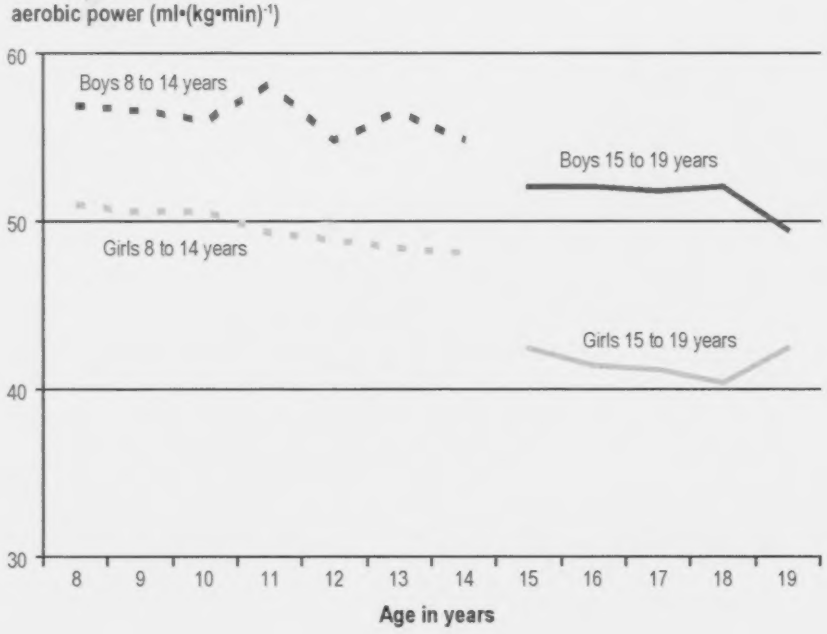
Response, non-response and screen-out rates for the CHMS fitness tests are given in Appendix Table A. Appendix Table B compares screen-out rates for the mCAFT for the CHMS with those for the CFS fitness test. Sample sizes for CHMS fitness measures are given in Appendix Table C. Among respondents who participated in the examination centre component of the survey, partial non-response (opting out of certain tests or portions of tests) to the fitness tests and anthropometric measures was rare.

Results

Response outcomes

Most children and youth who participated in the examination centre component of the CHMS completed all four fitness tests. Virtually everyone completed the flexibility (sit-and-reach) and muscular strength (grip strength) tests, and were assigned scores (Appendix Table A). Some were screened out of the aerobic fitness test (mCAFT) and the muscular endurance test (partial curl-ups), most because of health problems they reported during the screening component.

Figure 1
Median predicted maximal aerobic power (ml·(kg·min)$^{-1}$), by sex and age, household population aged 8 to 19 years, Canada, March 2007 to February 2009



Note: Equation for predicted maximal aerobic power has not been validated for children aged 8 to 14 years.
Source: 2007-2009 Canadian Health Measures Survey

Relatively high percentages of 15- to 19-year-olds were screened out of the mCAFT (18% of girls and 17% of boys) and the partial curl-up test (14% of girls and 13% of boys). Based on their body composition measurements, those who were screened out tended to be less fit. For example, among those screened out of the mCAFT, mean BMI was 24.1 kg/m^2 and mean waist circumference was 80.4 cm, compared with a mean BMI of 23.2 kg/m^2 and a mean waist circumference of 78.0 cm among those who completed the test. Some younger children had difficulty with the mCAFT because of an inability to maintain the proper stepping cadence. This was especially the case for 8- to 10-year-olds, among whom 19% of boys and 13% of girls were not assigned VO_2max scores for this reason.

Body composition measurements were taken for virtually all children and youth who participated in the examination centre component (Appendix Table C).

Fitness measures

Predicted maximal aerobic power (VO_2max) declined with age for both boys and girls (Figure 1). However, these results should be interpreted with caution, because the equation for VO_2max has not been validated for children aged 8 to 14 years. At all ages, boys had higher VO_2max values than did girls.

Based on the sit-and-reach test, girls were more flexible than boys (Table 1). Flexibility scores were fairly stable across the three age groups for both sexes.

At ages 8 to 10 years, 28% of boys and 23% of girls were unable to complete even one partial curl-up. However, boys aged 15 to 19 years excelled at this test, with 64% completing 25 partial curl-ups. Girls in all three age groups tended to fall in the middle group, completing between one and 24 curl-ups.

In all three age groups, boys' mean scores for grip strength were higher than those of girls, and as might be expected, grip strength increased at older ages for both sexes.

BMI rose with age, although average BMIs were similar for boys and girls in all

Table 1
Descriptive statistics for selected fitness measures, by sex and age group, household population aged 6 to 19 years, Canada, March 2007 to February 2009

	6 to 10 (8 to 10) years[‡]			11 to 14 years			15 to 19 years		
		95% confidence interval			95% confidence interval			95% confidence interval	
Fitness measure and sex	Estimate	from	to	Estimate	from	to	Estimate	from	to
Aerobic fitness: predicted maximal aerobic power (ml • (kg • min)$^{-1}$)[§]									
Mean									
Boys	56.3[†]	55.7	56.8	54.9[†]	54.5	55.4	50.8	49.5	52.0
Girls	50.7[†*]	50.2	51.3	48.9[†*]	48.3	49.5	42.2[*]	41.6	42.8
Standard deviation									
Boys	3.5	..	..	3.4	..	..	5.8	..	..
Girls	3.8	..	..	4.0	..	..	4.3	..	..
50th percentile									
Boys	56.5[†]	55.3	57.7	55.7[†]	54.9	56.5	51.4	50.7	52.1
Girls	50.6[†*]	50.4	50.8	48.8[†*]	48.5	49.1	42.0[*]	41.1	42.9
Flexibility: sit-and-reach (cm)									
Mean									
Boys	24	23	26	21	20	23	23	22	24
Girls	29[*]	29	30	28[*]	27	29	30[*]	28	32
Standard deviation									
Boys	7	..	..	8	..	..	9	..	..
Girls	8	..	..	9	..	..	11	..	..
50th percentile									
Boys	25	24	27	22	19	24	24	23	25
Girls	30[*]	28	31	29[*]	27	30	29[*]	25	33
Muscular endurance: number of partial curl-ups in one minute (maximum 25)									
% completing zero									
Boys	28[†]	23	33	<10	..	..	4[‡]	2	7
Girls	23[†‡]	15	31	<10	..	..	10[*]	7	13
% completing 1 to 24									
Boys	61[†]	54	69	51[†]	41	60	32	26	37
Girls	64	55	72	56	52	61	52[*]	41	62
% completing 25									
Boys	11[†‡]	5	17	44[†]	32	55	64	58	70
Girls	13[†‡]	8	18	38	33	43	38[*]	26	50
Muscular strength: grip strength (kg)									
Mean									
Boys	25[†]	24	27	51[†]	48	54	85	81	89
Girls	23[†*]	21	24	42[†*]	41	43	54[*]	52	56
Standard deviation									
Boys	8	..	..	17	..	..	18	..	..
Girls	9	..	..	10	..	..	10	..	..
50th percentile									
Boys	25[†]	23	27	46[†]	43	49	85	79	91
Girls	22[†*]	20	24	41[†*]	40	42	54[*]	52	56
Body mass index (kg/m^2)									
Mean									
Boys	17.7[†]	17.3	18.1	20.6[†]	19.8	21.3	23.8	22.6	25.1
Girls	17.1[†*]	16.8	17.4	20.4[†]	19.9	21.0	23.1	22.5	23.8
Standard deviation									
Boys	2.9	..	..	4.4	..	..	5.3	..	..
Girls	3.2	..	..	3.8	..	..	4.6	..	..
50th percentile									
Boys	16.9[†]	16.5	17.3	19.3[†]	18.7	20.0	22.4	21.6	23.1
Girls	16.3[†*]	16.1	16.6	19.7[†]	19.0	20.5	22.0	21.3	22.7
Waist circumference (cm)									
Mean									
Boys	61[†]	59	62	71[†]	69	74	81	78	84
Girls	58[†*]	57	59	70[†]	68	72	77[*]	75	78
Standard deviation									
Boys	9	..	..	12	..	..	13	..	..
Girls	9	..	..	10	..	..	12	..	..
50th percentile									
Boys	59[†]	57	60	68[†]	66	70	77	75	80
Girls	56[†*]	55	56	69[†]	67	71	73[*]	71	75
Sum of five skinfolds (mm)[¶]									
Mean									
Boys	48	44	52	54[†]	51	58	48	46	51
Girls	50[†]	47	53	67[†*]	61	73	79[*]	75	82
Standard deviation									
Boys	27	..	..	30	..	..	22	..	..
Girls	24	..	..	29	..	..	27	..	..
50th percentile									
Boys	36	32	40	44	41	46	41	37	45
Girls	42[†*]	39	44	61[†*]	52	69	74[*]	67	81
Waist-to-hip ratio									
Mean									
Boys	0.84	0.84	0.84	0.82	0.81	0.83	0.83	0.81	0.84
Girls	0.82[†*]	0.82	0.83	0.80[†*]	0.78	0.81	0.77[*]	0.76	0.79
Standard deviation									
Boys	0.05	..	..	0.06	..	..	0.06	..	..
Girls	0.05	..	..	0.06	..	..	0.06	..	..
50th percentile									
Boys	0.84[†]	0.84	0.84	0.81	0.80	0.82	0.82	0.81	0.83
Girls	0.82[†*]	0.81	0.83	0.79[†*]	0.78	0.80	0.76[*]	0.75	0.77

* significantly different from estimate for boys ($p < 0.05$)
† significantly different from estimate for 15- to 19-year-olds ($p < 0.05$)
‡ 6- and 7-year-olds excluded from estimates for aerobic fitness and muscular endurance (partial curl-ups)
§ equation for predicted maximal aerobic power (ml•(kg•min)$^{-1}$) has not been validated for children younger than 15 years
¶ excludes respondents with BMI 30.0 kg/m^2 or higher
‡ use with caution (coefficient of variation 16.6% to 33.3%)
.. not applicable
Note: If coefficient of variation of estimate is greater than 33%, estimate is indicated as being less than upper limit of 95% confidence interval.
Source: 2007-2009 Canadian Health Measures Survey.

three age groups. Waist circumference, too, increased with age. Average waist circumference was similar for boys and girls aged 11 to 14 years, but in the older and younger age groups, boys' average waist circumference was larger.

Skinfold measurements were taken for children and adolescents whose BMI was less than 30.0 kg/m^2 (94% of boys and girls). At ages 11 to 14 years, boys' average skinfold measurements were higher than at ages 6 to 10 or 15 to 19 years. Among girls, average skinfold measurements rose with age, and in the two older age groups, girls had higher average skinfold measurements than did boys.

Girls aged 6 to 10 years had higher waist-to-hip ratios than did 15- to 19-year-olds. In all three age groups, girls' waist-to-hip ratios were lower than those of boys.

Health benefit ratings

Based on their fitness measures, 15- to 19-year-olds were assigned health benefit ratings (Table 2). To provide context, these ratings are compared with those for adults aged 20 to 39 years. The "excellent" and "very good" categories and the "fair" and "needs improvement" categories were combined to ensure sufficient sample size for all measures. Health benefit ratings for aerobic and musculoskeletal fitness are based on age-specific cut-offs that take account of expected changes in these measures that occur with age.[30]

At ages 15 to 19 years, 32% of boys and 20% of girls had VO_2max scores that placed them in the fair/ needs improvement category. Percentages were much higher among 20- to 39-year-olds: 46% of men and 37% of women.

More than two-thirds (68%) of boys and 59% of girls aged 15 to 19 years had sit-and-reach (*flexibility*) scores that placed them in the fair/needs improvement category, similar to the percentages for 20- to 39-year-olds. Teens and young adults also had similar ratings for *muscular endurance*—38% of teenage girls and 20% of teenage boys were in the fair/needs improvement category. Just

Table 2
Percentage distribution of health benefit ratings of selected fitness measures, by sex, household population aged 15 to 19 years and 20 to 39, Canada, March 2007 to February 2009

	15 to 19 years			20 to 39 years		
		95% confidence interval			95% confidence interval	
Health benefit rating and sex	%	from	to	%	from	to
Aerobic fitness health benefit zone						
Fair/Needs improvement						
Boys	32[†]	24	39	46	41	51
Girls	20[†*]	14	25	37*	31	44
Good						
Boys	31	24	38	26	20	33
Girls	54[†*]	47	62	40*	37	44
Excellent/Very good						
Boys	38[†]	31	45	27	19	36
Girls	26*	19	34	23	16	29
Flexibility (sit-and-reach) health benefit zone						
Fair/Needs improvement						
Boys	68	62	74	61	55	66
Girls	59*	49	69	55	52	59
Good						
Boys	19	13	24	16	12	21
Girls	12[†]	8	16	16	12	19
Excellent/Very good						
Boys	13[†]	8	19	23	19	27
Girls	30*	21	38	25*	26	32
Muscular endurance (partial curl-up) health benefit zone						
Fair/Needs improvement						
Boys	20[†]	13	27	19	14	23
Girls	38*	28	47	46*	41	52
Good						
Boys	<10			7[†]	4	9
Girls	9	7	12	10	7	13
Excellent/Very good						
Boys	74	68	80	75	70	80
Girls	53*	44	62	44*	39	49
Muscular strength (grip strength) health benefit zone						
Fair/Needs improvement						
Boys	59[†]	51	67	42	35	49
Girls	47[†*]	38	55	56*	50	61
Good						
Boys	19[†]	13	25	24[†]	15	32
Girls	27[†]	22	32	18	14	22
Excellent/Very good						
Boys	22[†]	17	27	34	27	42
Girls	27	20	33	27	19	34
Overall musculoskeletal health benefit zone[‡]						
Fair/Needs improvement						
Boys	46[†]	36	55	30	25	36
Girls	47	37	56	51*	46	56
Good						
Boys	30	21	39	32	26	38
Girls	29	20	38	28	23	33
Excellent/Very good						
Boys	25[†]	19	31	38	31	44
Girls	24[†]	16	33	21*	17	24
Body mass index category[§]						
Obese						
Boys	14[†]	6	22	19	15	23
Girls	10[†]	7	13	21	16	25
Overweight						
Boys	17[†]	12	22	37	30	45
Girls	16[†]	12	20	23*	17	30
Normal weight						
Boys	69[†]	60	77	43	37	48
Girls	74[†]	69	80	50	41	60
Waist circumference health risk						
High risk						
Boys	<13[†]			21	18	24
Girls	17[†*]	12	21	31*	25	37
Increased risk						
Boys	<12[†]			14	11	18
Girls	11[†]	5	17	17[†]	11	23
Low risk						
Boys	85[†]	78	93	65	61	69
Girls	72[†*]	64	80	52*	43	61
Body composition health benefit zone[¶]						
Fair/Needs improvement						
Boys	<13[†]			20	17	23
Girls	15[†]	9	20	29*	23	34
Good						
Boys	<11	..	..	<5	..	..
Girls	<4	..	..	<6	..	..
Excellent/Very good						
Boys	86[†]	79	94	77	73	82
Girls	84[†]	79	88	68*	61	74
Back fitness health benefit zone[**]						
Fair/Needs improvement						
Boys	13[†]	10	16	22	18	25
Girls	22[†]	13	31	30*	24	36
Good						
Boys	29	23	35	21	15	27
Girls	14*[†]	8	20	17	12	22
Excellent/Very good						
Boys	58	52	65	58	53	62
Girls	64[†]	56	72	53	47	59

* significantly different from estimate for boys ($p < 0.05$)
† significantly different from estimate for 20- to 39-year-olds ($p < 0.05$)
‡ based on flexibility, muscular endurance and muscular strength
§ estimates for underweight not reported because of small sample sizes
¶ based on BMI, waist circumference and sum of five skinfolds
** based on flexibility, muscular endurance and waist circumference
E use with caution (coefficient of variation 16.6% to 33.3%)
.. not applicable

Note: If coefficient of variation of estimate is greater than 33%, estimate is indicated as being less than upper limit of 95% confidence interval.
Source: 2007-2009 Canadian Health Measures Survey.

under half (47%) of teenage girls were in the fair/needs improvement category for *muscular strength*, compared with 59% of teenage boys. Men aged 20 to 39 years fared better than teenage boys, with 42% being assessed this low rating. However, women aged 20 to 39 did not score as well as teenage girls, with 56% in the fair/needs improvement category.

Based on a combination of their flexibility, muscular endurance and muscular strength scores, almost half of 15- to 19-year-olds were assessed as fair/needs improvement for *musculoskeletal health*; slightly less than a third were assessed as good; and the remaining quarter, as very good/excellent. Teenage boys' ratings were not as favourable as those of men aged 20 to 39 years; teenage girls and women aged 20 to 39 years had similar ratings.

For all body composition measurements, teens' health benefit ratings were better than those of 20- to 39-year-olds. Teens were more likely to have BMIs that placed them in the normal weight group, less likely to have waist circumferences that placed them in the high-risk group, and for the composite measure based on BMI, waist circumference and the sum of five skinfolds, smaller percentages were in the fair/needs improvement category.

The back fitness of 13% of boys and 22% of girls aged 15 to 19 years was assessed as fair/needs improvement. The corresponding figures among 20- to 39-year-olds were higher, at 22% for men and 30% for women.

Comparisons with 1981

Where comparable tests were administered for flexibility and muscular strength and similar anthropometric measurements were taken, CHMS results were compared with data collected in the 1981 Canadian Fitness Survey (CFS). To make estimates more comparable, respondents screened out of the aerobic fitness test were excluded from CHMS estimates of flexibility and muscular strength (see *Methods*). Screen-out rates (based on the aerobic fitness test) for the two surveys are given in Appendix Table B. Screen-out rates were similar between the two surveys for children aged 7 to 10 and 11 to 14 years, but much higher percentages of 15- to 19-year-olds were screened out in 2007-2009 than in 1981.

Fitness scores for children and adolescents were less favourable in 2007-2009 than in 1981 (Table 3). For boys and girls in all age groups, flexibility and muscular strength scores were lower in 2007-2009, and mean BMI, waist circumference and the sum of five skinfolds were higher.

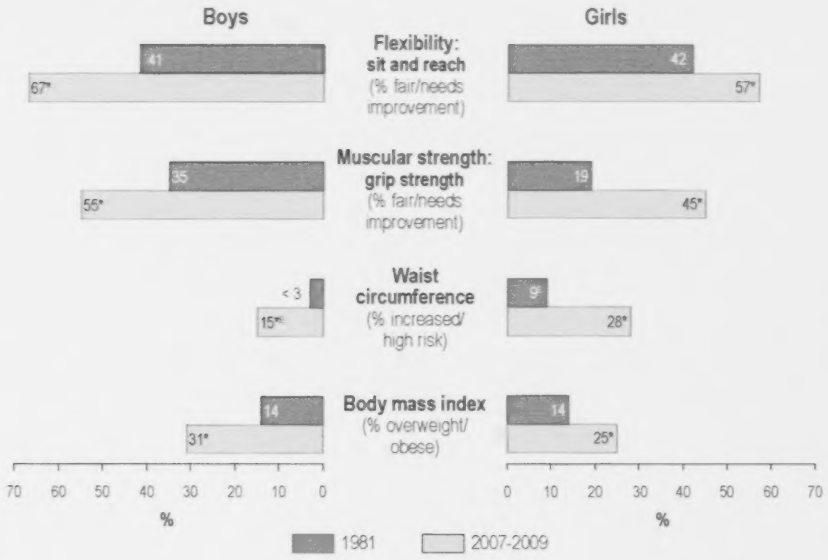
Compared with 1981, in 2007-2009, higher percentages of boys and girls aged 15 to 19 years were in the fair/needs improvement category for flexibility and muscular strength (Figure 2). The percentage in the increased/high-risk waist circumference category more than tripled for both sexes. The percentage classified as overweight or obese rose from 14% to 31% among boys, and from 14% to 25% among girls. For overall body composition, the percentage assigned to the bottom three categories (good/

Table 3
Mean and median values for selected fitness measures, by sex and age group, household population aged 7 to 19 years, Canada, 1981 and 2007-2009

Fitness measure, sex and survey year	7 to 10 years		11 to 14 years		15 to 19 years	
	Mean	Median	Mean	Median	Mean	Median
Flexibility: sit-and-reach (cm)						
Boys						
1981	27	28	26	27	30	30
2007-2009	24*	25*	21*	22*	24*	24*
Girls						
1981	32	32	32	33	34	35
2007-2009	29*	29*	28*	29*	30*	29*
Muscular strength: grip strength (kg)						
Boys						
1981	32	32	57	53	96	96
2007-2009	27*	28*	51*	46*	86*	87*
Girls						
1981	29	28	48	47	60	60
2007-2009	24*	24*	42*	41*	54*	54*
Body mass index (kg/m²)						
Boys						
1981	16.8	16.3	18.9	18.4	21.9	21.4
2007-2009	18.1*	17.4*	20.6*	19.3*	23.8*	22.4*
Girls						
1981	16.9	16.4	19.3	19.1	21.6	21.1
2007-2009	17.4*	16.5	20.4*	19.7	23.1*	22.0*
Waist circumference (cm)						
Boys						
1981	59	58	67	66	76	75
2007-2009	62*	60*	71*	68	81*	77
Girls						
1981	58	57	64	64	69	68
2007-2009	59*	57	70*	69*	77*	73*
Sum of five skinfolds (mm)†						
Boys						
1981	37	32	43	37	43	37
2007-2009	51*	39*	54*	44*	48*	41
Girls						
1981	47	42	55	50	64	60
2007-2009	52*	45	67*	61*	79*	74*

* significantly different from estimate for 1981 ($p < 0.05$)
† excludes respondents with BMI 30.0 kg/m² or more
Note: To make estimates more comparable, Canadian Health Measures Survey estimates for flexibility and muscular strength exclude respondents screened out of aerobic fitness test (see *Methods*).
Source: 1981 Canada Fitness Survey; 2007-2009 Canadian Health Measures Survey.

Figure 2
Percentage with suboptimal health benefit ratings for selected anthropometric measures, by sex, household population aged 15 to 19 years, Canada, 1981 and 2007-2009



* significantly higher than estimate for 1981 ($p<0.05$)
‡ use with caution (coefficient of variation 16.6% to 33.3%)
Note: To make estimates more comparable, Canadian Health Measures Survey estimates for flexibility and muscular strength exclude respondents screened out of aerobic fitness test (see *Methods*). If coefficient of variation of estimate is greater than 33.3%, estimate is indicated as being less than upper limit of 95% confidence interval
Sources: 1981 Canada Fitness Survey; 2007-2009 Canadian Health Measures Survey.

fair/needs improvement; combined to ensure adequate sample sizes) more than quadrupled from less than 2% to 14% for boys, and from 4% to 16% for girls (not shown in Figure 2).

A typical 12-year-old

Figure 3 depicts a typical 12-year-old boy and girl in 1981 and in 2007-2009. In 2007-2009, a 12-year-old boy was, on average, about 5 cm (2 inches) taller than his 1981 counterpart and weighed 6.4 kg (14 pounds) more. His waist circumference was 1.3 cm larger, his hip circumference 6.0 cm larger, and his BMI had increased by 1.1 kg/m^2. His grip strength had declined by 5 kg, and his score in the sit-and-reach test decreased by 5.1 cm.

In 2007-2009, a typical 12-year-old girl was 2.8 cm (1.1 inches) taller than her 1981 counterpart, and she weighed 4.9 kg (11 pounds) more. Her waist circumference was 5.6 cm larger, her hip circumference 4.8 cm larger, and her BMI had risen by 1.1 kg/m^2. Her grip strength had declined by 3 kg, and her score on the sit-and-reach test had decreased by 3.8 cm.

Discussion

Nationally representative data on the fitness of Canadian children and youth have not been available in two decades, a period that saw a remarkable rise in childhood obesity.[6-8] Using data from cycle 1 of the Canadian Health Measures Survey, this paper provides an important update, demonstrating that fitness levels have declined significantly and meaningfully since 1981; that significant sex differences exist for most measures of fitness; that fitness levels change substantially from age 6 through 19 years; and that 15- to 19-year-olds generally have better health benefit ratings for aerobic fitness and body composition than do adults aged 20 to 39, but results for musculoskeletal fitness are mixed. Overall, the patterns by age and sex in the CHMS are consistent with those in the 1981 CFS. Sex and age-related differences reflect complex and interconnected effects of genetics, anatomy, physiology, behaviour and social and physical environments.

Fitness testing of children and youth has been done in Canada and the United States with varying degrees of rigour for more than 50 years,[45] but the lack of standardization in test protocols makes it difficult to assess temporal trends. School-based fitness testing was common in Canada in the 1960-to-1980 period, but testing protocols were oriented toward performance-related fitness (for example, standing long jump, 50-metre sprint, flexed arm hang)[46-48] rather than health-related fitness,[30] which is the focus of measures in the CHMS.

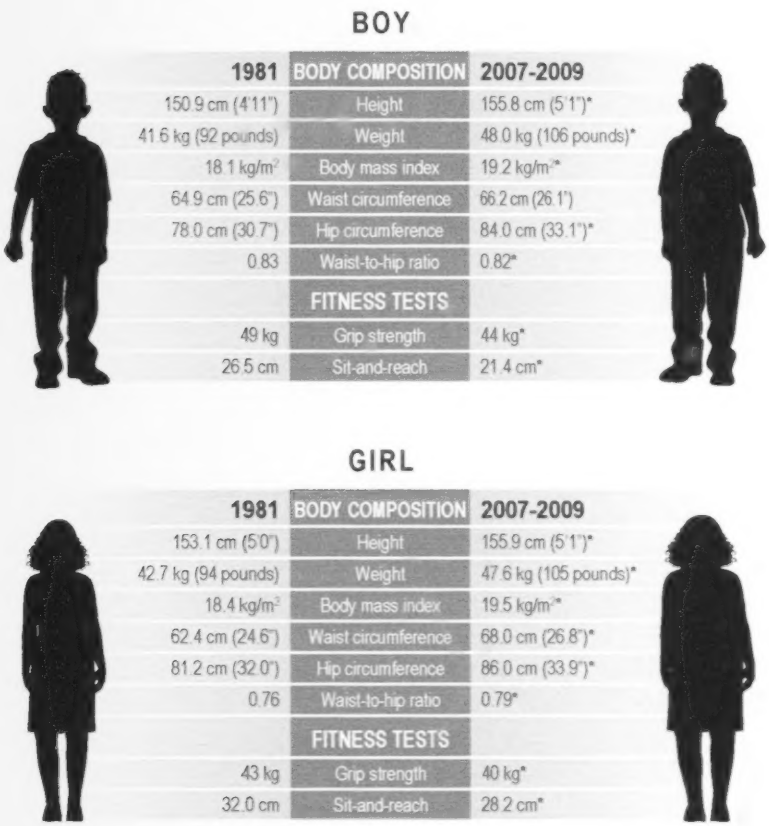
Body composition

The estimates of height and weight of a typical 12-year-old boy and girl from the CHMS are significantly greater than those for age-matched counterparts from the CFS. This upward trend in height and weight has been evident in developed countries since the early 19th century and likely reflects a combination of improved health and nutrition, accelerated maturation, and more favourable living conditions.[49]

Indicators of body composition (BMI, waist circumference, skinfold measures) increased substantially between 1981 and 2007-2009. These direct measures of adiposity further verify previously reported trends[6-8] and provide strong evidence that the increases in childhood obesity and overweight based on BMI are related to greater adiposity, not greater muscularity.

Girls had higher mean skinfolds than did boys, but generally had lower

Figure 3
Portrait of typical 12-year-old boy and girl, 1981 and 2007-2009



* significantly different from estimate for 1981 ($p<0.05$)
Note: Estimates are based on median values for boys and girls aged 11 to 13 years. To make estimates more comparable, Canadian Health Measures Survey estimates for flexibility and muscular strength exclude respondents screened out of aerobic fitness test (see *Methods*).
Sources: 1981 Canada Fitness Survey; 2007-2009 Canadian Health Measures Survey

waist circumferences and waist-to-hip ratios. Mean BMIs were similar. Earlier Canadian studies showed that while BMI was equivalent, levels of subcutaneous fat as measured by the sum of skinfolds were higher among girls and that BMI in boys and girls and sum of skinfolds in girls increased with age.[21,22]

Compared with results from the Amsterdam Growth and Health Longitudinal Study,[50,51] which began in 1974 and followed participants for 32 years, the BMI of Canadian children aged 11 to 14 years is approximately 3 units (kg/m²) higher for boys and 4 units higher for girls. If the BMI of Canadian children follows trajectories over the next few decades similar to those of the Amsterdam children, the average 11- to 14-year-old Canadian of today will be overweight by age 36 years.

Aerobic fitness

Because of refinements in the aerobic fitness measures used in the CPAFLA (mCAFT) over time, direct comparisons of aerobic fitness between the CFS and the CHMS are difficult, and require additional analyses beyond the scope of this paper. Based on field fitness testing, global temporal trend data demonstrate a worldwide decrease in pediatric aerobic fitness[16,52] that cannot be explained solely by the increase in child adiposity.[53] These findings suggest that a decrease in physical activity and subsequent detraining effect are likely at least partially responsible for the decline in aerobic fitness.[53] Absolute comparisons of aerobic fitness results to international data are hampered by the lack of data using the same protocol (mCAFT) and the lack of a validated method to convert mCAFT scores to VO_2max in children younger than 15 years.

In the CHMS, aerobic fitness was higher in boys than girls and decreased with age among both sexes, consistent with previous Canadian findings.[21] Recent data from the United States National Health and Nutrition Examination Survey also showed significantly higher estimated VO_2max in boys than girls aged 12 to 19 years and an increase in maximal aerobic power with age in boys, but a decrease with age in girls.[54] Age-related declines may be due to less physical activity, increased adiposity, or changes in hemodynamic and/or metabolic functions associated with growth and development.[49] Although the age-related decline in aerobic fitness (expressed relative to body weight) through childhood is well documented,[49] routine participation in moderate to vigorous physical activity could slow or reverse this trend.[55]

The age- and sex-matched median predicted maximal aerobic power values from the United States[54] are lower than the Canadian values reported in Figure 1. The differences may reflect higher aerobic fitness among Canadian children and youth, fundamental differences in testing protocols, problems with the equation used to predict maximal aerobic power in Canadian children and youth (not validated for children younger than 15 years), or some combination of explanations. The mCAFT uses age-predicted maximum heart rate (220 – age) to determine the heart rate at which the test is completed. Because maximal heart

What is already known on this subject?

- Childhood obesity has risen significantly over the past 20 to 30 years.
- Excess adiposity in childhood is associated with elevated cardio-metabolic disease risk.
- Even in childhood, strong evidence indicates a direct relationship between fitness and health.
- Boys generally demonstrate better aerobic fitness and strength than girls, while girls demonstrate better flexibility.
- Aerobic fitness, relative to body weight, declines with age through childhood and adolescence and is lower in girls than boys.

What does this study add?

- At age 12 years, Canadian boys and girls are now taller and heavier than in 1981.
- Based on a variety of direct measures of anthropometry from the Canadian Health Measures Survey, the body composition of Canadian children and youth is less healthy than in 1981.
- The strength and flexibility of boys and girls has declined significantly since 1981.
- Increases in childhood obesity and overweight are related to increased adiposity, not greater muscularity.

rate does not change much in childhood, this methodology may affect predicted maximal aerobic power results. Further research is required to substantiate these potential explanations.

VO_2max estimates for Canadian children aged 11 to 14 years appear slightly lower than earlier estimates from a sample of 13-year-olds in the Amsterdam Growth and Health Longitudinal Study in 1974.[50,51] At age 36 years, VO_2max estimates for these participants were about 50 ml•(kg•min)$^{-1}$ for men and 40 ml•(kg•min)$^{-1}$ for women, which are higher than estimates for men and equivalent to those for women aged 20 to 39 years in the CHMS.[42] Based on this age-related decline of VO_2max and the secular trend toward poorer fitness levels indicated by a comparison between the CHMS and CFS, it is likely that when these 11- to 14-year-old Canadians are adults, their fitness profile will be poorer than that of current adults.

Musculoskeletal fitness

Significantly lower flexibility and muscular strength scores were observed for boys and girls of all ages in the CHMS, compared with the 1981 CFS. Prospective, longitudinal studies examining health-related outcomes related to flexibility and strength through childhood are lacking, as are international comparisons that employed similar measurement protocols. However, studies of communities that have not adopted modern technology and lifestyles are useful bases of comparison. Results for Canadian Old Order Amish and Old Order Mennonite children indicate that their grip strength is approximately 50% higher than the results obtained from the CHMS.[56,57]

Muscular strength was higher in boys than in girls and increased with age among both sexes. Girls had better flexibility scores than did boys at all ages, and there was no age-related difference in mean flexibility scores. Neither of these findings is new, and they reaffirm patterns observed in earlier surveys.[21,22]

The muscular endurance test is influenced by floor and ceiling effects (Table 1). Nonetheless, results seem to improve with age, with boys aged 15 to 19 years performing better than girls. Further research on the validity and reliability of this test for children younger than 15 years is required.

Limitations

The findings in this study have important limitations that should be considered when interpreting the results. Most notably, the screening criteria for the various fitness tests, which were employed to ensure respondent safety, could have biased the sample. For example, the mean BMI of the 17% of 15- to 19-year-olds screened out of the aerobic fitness test was 24.1 kg/m^2, compared with 23.2 kg/m^2 among those who completed the test, indicating that those who were screened out were heavier.

As much as possible, the fitness tests and anthropometric measures in the CHMS were selected for their similarity to those in the CFS. However, differences in the sample design, the educational and training requirements of survey administrators, the testing venue, and response rates and weighting procedures may have weakened the comparability of estimates.

Maximal aerobic power in children is most often referred to as "peak VO_2" rather than VO_2max, as is often used in adults. This difference highlights the challenge of getting directly measured "true" maximal tests from children.[58] The adult convention of expressing VO_2max relative to body weight (for example, O_2 per kg per min) has been challenged in the pediatric literature because of strong evidence demonstrating a non-linear relationship between peak VO_2 and body mass during growth and maturation.[39,58] However, no allometric scaling was performed on the data in these analyses. Furthermore, as previously noted, the equation for calculating VO_2max has not been validated for chidren younger than 15 years.

It was noted during field observations that some younger children had difficulty performing the partial curl-up test for reasons other than level of muscular endurance. Thus, 6- and 7-year-olds were excluded from CHMS estimates. Difficulty performing the test may also explain, in part, the high percentage of 8- to 10-year-olds who completed no curl-ups.

The overall non-response rate to the CHMS was 46.5%. Although adjustments were made to the sampling weights to compensate, CHMS estimates may be biased if there were systematic differences between respondents and non-respondents. One concern is the possibility that less-fit individuals may have been less likely to participate, particularly in the examination centre component of the survey. To assess this source of bias, estimates of overweight/obesity from the 2007-2009 CHMS were compared with those from the 2008 Canadian Community Health Survey (CCHS) that were based on measured height and weight. Among 12- to 19-year-olds, the estimated prevalence of overweight/obesity according to 2008 CCHS data was 30.8%, somewhat higher than the CHMS estimate of 28.2%, which suggests that CHMS data may overestimate fitness levels to some extent. The same concern about bias may also apply to the CFS estimates. Based on CFS data, 13.1% of children aged 7 to 19 years were overweight/obese in 1981, compared with the estimate of 13.9% based on data from the 1978/1979 Canada Health Survey.[20]

Finally, it is possible that secular changes in the timing and tempo of maturation influenced the results. The comparisons in Figure 3 should be interpreted with this possibility in mind.

Conclusions

This paper provides the first comprehensive assessment of the fitness of Canadian children and youth in a generation. The results demonstrate a significant deterioration since 1981, regardless of sex or age. In particular, muscular strength and flexibility have decreased, and all measures of adiposity have increased. Children are taller, heavier, fatter and weaker than in 1981. Previous research predicts that a population decline in fitness, as observed here, may result in accelerated non-communicable disease development, increased health care costs, and loss of future productivity.[5,10-15,17,49,59] Ongoing surveillance of fitness through the Canadian Health Measure Survey will be important for monitoring trends, examining relationships between fitness and health, and assessing future interventions designed to improve the fitness of the nation. ■

References

1. Tremblay MS. Major initiatives related to childhood obesity and physical inactivity in Canada: the year in review. *Canadian Journal of Public Health* 2007; 98: 457-9.
2. Active Healthy Kids Canada. *2008 Report Card on Physical Activity for Children and Youth*. Active Healthy Kids Canada, 2008. [cited 2009 July 4] Available at: http://www.activehealthykids.ca/ReportCard/ArchivedReportCards.aspx.
3. Active Healthy Kids Canada. *2009 Report Card on Physical Activity for Children and Youth*. Active Healthy Kids Canada, 2009. [cited 2009 July 4] Available at: http://www.activehealthykids.ca/ReportCard/2009ReportCard0verview.aspx.
4. Leitch KK. *Reaching for the Top: A Report by the Advisor on Healthy Children and Youth*. Health Canada (Catalogue H21-296/2007E) Ottawa: Minister of Public Works and Government Services Canada, 2007.
5. House of Commons Canada. *Healthy Weights for Healthy Kids: Report of the Standing Committee on Health*. Ottawa: Communication Canada – Publishing, 2007.
6. Tremblay MS, Willms JD. Secular trends in body mass index of Canadian children. *Canadian Medical Association Journal* 2000; 163: 1429-33; erratum 2001; 164(7): 970.
7. Tremblay MS, Katzmarzyk PT, Willms JD. Temporal trends in overweight and obesity in Canada, 1981-1996. *International Journal of Obesity and Related Metabolic Disorders* 2002; 26: 538-43.
8. Shields M. Overweight and obesity among children and youth. *Health Reports* (Statistics Canada, 82-003) 2006; 17(3): 27-42.
9. Canadian Fitness and Lifestyle Research Institute. *Kids CAN PLAY!* [cited 2009 July 31] Available at: http://www.cflri.ca/eng/statistics/surveys/documents/CANPLAY_2008_bl.pdf.
10. Ball GDC, McCargar LJ. Childhood obesity in Canada: a review of prevalence estimates and risk factors for cardiovascular diseases and type 2 diabetes. *Canadian Journal of Applied Physiology* 2003; 28: 117-40.
11. Janssen I. Physical activity guidelines for children and youth. *Applied Physiology, Nutrition and Metabolism* 2007; 32(Suppl.2E): S109-S121.
12. Strong WB, Malina RM, Blimkie CJ, et al. Evidence based physical activity for school-age youth. *Journal of Pediatrics* 2005; 146: 732-7.
13. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report, 2008*. Washington, DC: U.S. Department of Health and Human Services, 2008.
14. Katzmarzyk PT, Baur LA, Blair SN, et al. International conference on physical activity and obesity in children: summary statement and recommendations. *International Journal of Pediatric Obesity* 2008; 3: 3-21.
15. Andersen LB, Harro M, Sardinha LB, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet* 2006; 368: 299-304.
16. Tomkinson GR, Leger LA, Olds TS, Cazorla G. Secular trends in the performance of children and adolescents (1980-2000). *Sports Medicine* 2003; 33: 285-300.
17. Anderssen SA, Cooper AR, Riddoch C, et al. Low cardiorespiratory fitness is a strong predictor for clustering of cardiovascular disease risk factors in children independent of country, age and sex. *European Journal of Cardiovascular Disease Prevention and Rehabilitation* 2007; 14: 526-31.
18. Ekelund U, Anderssen SA, Froberg K, et al. Independent associations of physical activity and cardiorespiratory fitness with metabolic risk factors in children: the European Youth Heart Study. *Diabetologia* 2007; 50: 1832-40.
19. Nutrition Canada. *Nutrition – A National Priority* (Catalogue H58-36) Ottawa: Department of National Health and Welfare, 1973.
20. Canada Health Survey. *The Health of Canadians: Report of the Canada Health Survey* (Catalogue 82-538) Ottawa: Health and Welfare Canada/Statistics Canada, 1981.
21. Canada Fitness Survey. *Fitness and Lifestyle in Canada*. Ottawa: Minister of Fitness and Amateur Sport, 1983.

22. Stephens T, Craig CL. *The Well-Being of Canadians: Highlights of the 1988 Campbell's Survey*. Ottawa: Canadian Fitness and Lifestyle Research Institute, 1990.

23. Tremblay MS, Connor Gorber, S. Canadian Health Measures Survey: brief overview. *Canadian Journal of Public Health* 2007; 98: 453-6.

24. Tremblay MS, Wolfson M, Connor Gorber S. Canadian Health Measures Survey: background, rationale and overview. *Health Reports* (Statistics Canada, Catalogue 82-003) 2007; 18(Suppl.): 7-20.

25. Bryan S, St-Denis M, Wojtas D. Canadian Health Measures Survey: Clinic operations and logistics. *Health Reports* (Statistics Canada, Catalogue 82-003) 2007; 18(Suppl.): 53-70.

26. Day B, Langlois R, Tremblay M, et al. Canadian Health Measures Survey: Ethical, legal and social issues. *Health Reports* (Statistics Canada, Catalogue 82-003) 2007; 18(Suppl.): 37-52.

27. Giroux S. Canadian Health Measures Survey: Sampling strategy overview. *Health Reports* (Statistics Canada, Catalogue 82-003) 2007; 18(Suppl): 31-6.

28. Canada Fitness Survey. *A User's Guide to CFS findings*. Ottawa: Canada Fitness Survey, 1983.

29. Canadian Fitness and Lifestyle Research Institute. *Canada Fitness Survey Household Survey: Micro-data tape documentation*. Ottawa: Canadian Fitness and Lifestyle Research Institute, 1992.

30. Canadian Society for Exercise Physiology. *The Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA) Third Edition*. Ottawa: Canadian Society for Exercise Physiology, 2003.

31. Statistics Canada. *Canadian Health Measures Survey (CHMS) Data Users' Guide: Cycle 01, September 2007*. Available at: www.statcan.gc.ca.

32. Statistics Canada. *Canadian Health Measures Survey (CHMS) Clinic Questionnaire: Cycle 01, September 2007*. Available at: www.statcan.gc.ca/imdb-bmdi/instrument/5071_Q2_V1-eng.pdf.

33. World Health Organization. *Physical Status: The Use and Interpretation of Anthropometry, Report of the WHO Expert Committee* (WHO Technical Report Series, No. 854) Geneva: World Health Organization, 1995.

34. Fitness Canada. *Canadian Standardized Test of Fitness (CSTF) Operations Manual. Third Edition*. Ottawa: Fitness and Amateur Sport, Government of Canada, 1986.

35. Health Canada. *Canadian Guidelines for Body Weight Classification in Adults* (Catalogue H49-179) Ottawa: Health Canada, 2003.

36. Cole TJ, Bellizzi MC, Flegal KM, et al. Establishing a standard definition for child overweight and obesity worldwide: international survey. *British Medical Journal* 2000; 320(7244): 1240-3.

37. Lau DC, Douketis JD, Morrison KM, et al. 2006 Canadian clinical practice guidelines on the management and prevention of obesity in adults and children [summary]. *Canadian Medical Association Journal* 2007; 176(8 Suppl.): Online 1-12.

38. World Health Organization. *Obesity: Preventing and Managing the Global Epidemic* (WHO Technical Report Series, No. 894) Geneva: World Health Organization, 2000.

39. Lean ME, Han TS, Morrison CE. Waist circumference as a measure for indicating need for weight management. *British Medical Journal* 1995; 311(6998): 158-61.

40. Weller IM, Thomas SG, Corey PN, et al. Prediction of maximal oxygen uptake from a modified Canadian aerobic fitness test. *Canadian Journal of Applied Physiology* 1993; 18(2): 175-88.

41. Weller IM, Thomas SG, Gledhill N, et al. A study to validate the modified Canadian Aerobic Fitness Test. *Canadian Journal of Applied Physiology* 1995; 20(2): 211-21.

42. Shields M, Tremblay MS, Laviolette M, et al. Fitness of Canadian adults: Results from the 2007-2009 Canadian Health Measures Survey. *Health Reports* (Statistics Canada, Catalogue 82-003) 2009; 21(1): online: 1-15.

43. Rao JNK, Wu CFJ, Yue K. Some recent work on resampling methods for complex surveys. *Survey Methodology* (Statistics Canada, Catalogue 12-001) 1992; 18(2): 209-17.

44. Rust KF, Rao JNK. Variance estimation for complex surveys using replication techniques. *Statistical Methods in Medical Research* 1996; 5: 281-310.

45. Morrow JR, Zhu W, Franks D, et al. 1958-2008: 50 years of youth fitness tests in the United States. *Research Quarterly for Exercise and Sport* 2009; 80: 1-11.

46. *Canada Fitness Award Manual*. Ottawa: Fitness and Amateur Sport, Government of Canada, 1984.

47. *CAHPER Fitness-Performance Test II Manual*. Ottawa: Canadian Association for Health Physical Education and Recreation, 1980.

48. *The CAHPER Fitness-Performance Test Manual – for Boys and Girls 7-17 years of age*. Ottawa: Canadian Association for Health Physical Education and Recreation, 1966.

49. Malina RM, Bouchard C, Bar-Or O. *Growth, Maturation, and Physical Activity (Second Edition)*. Champaign, Illinois: Human Kinetics Publishers, 2004.

50. Kemper HCG, Snel, J, van Mechelen W. General introduction. In: Kemper HCG (ed.) Amsterdam Growth and Health Longitudinal Study (AGAHLS): A 23-year follow-up from teenager to adult about lifestyle and health. *Medicine and Sport Science* 2004; 47: 5-20.

51. Koppes LLJ, Twisk JWR, Kemper HCG. Longitudinal trends, stability and error of biological and lifestyle characteristics. In: HCG Kemper (ed.) Amsterdam Growth and Health Longitudinal Study (AGAHLS): A 23-year follow-up from teenager to adult about lifestyle and health. *Medicine and Sport Science* 2004; 47: 45-63.

52. Tomkinson GR, Olds TS. Secular changes in pediatric aerobic fitness test performance: the global picture. In: Tomkinson GR, Olds TS (eds.) *Pediatric Fitness: Secular Trends and Geographic Variability*. Basel, Switzerland: Karger: 46-66.

53. Olds TS, Ridley K, Tomkinson GR. Declines in aerobic fitness: are they only due to increasing fatness? In: Tomkinson GR, Olds TS (eds.). *Pediatric Fitness: Secular Trends and Geographic Variability*. Basel, Switzerland: Karger: 226–40.

54. Pate RR, Wang C-Y, Dowda M, et al. Cardiorespiratory fitness levels among US youth 12 to 19 years of age. *Archives of Pediatric and Adolescent Medicine* 2006; 160: 1005-12.

55. Pfeiffer KA, Dowda M, Dishman RK, et al. Cardiorespiratory fitness in girls change from middle to high school. *Medicine and Science in Sports and Exercise* 2007; 39: 2234-41.

56. Tremblay MS, Esliger DW, Copeland JL, et al. Moving forward by looking back: Lessons learned from lost lifestyles. *Applied Physiology, Nutrition and Metabolism* 2008; 33: 836-42.

57. Tremblay MS, Barnes JD, Copeland JL, Esliger DW. Conquering childhood inactivity: Is the answer in the past? *Medicine and Science in Sports and Exercise* 2005; 37: 1187-94.

58. Armstrong N, Welsman JR. Aerobic fitness: what are we measuring? In: Tomkinson GR, Olds TS (eds.). *Pediatric Fitness: Secular Trends and Geographic Variability*. Basel, Switzerland: Karger: 5-25.

59. U.S. Department of Health and Human Services. *Physical Activity and Health: A Report of the Surgeon General*. Atlanta, Georgia: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, 1996.

Table A
Percentage distribution of participation outcomes for fitness tests, by sex and age group, household population aged 6 to 19 years, Canada, March 2007 to February 2009

Fitness test, outcome and sex	6 to 8 (8 to10) years[1]	11 to 14 years	15 to 19 years
	%		
Aerobic fitness test (mCAFT)			
Screened in			
Test completed			
Boys	76.1	88.8	80.0
Girls	79.1	91.8†	80.2
Test not done: trouble maintaining cadence			
Boys	18.5†	5.8	2.0
Girls	13.1†	3.6	0.7
Test not done: other reason[2]			
Boys	0.8	0.0	1.0
Girls	0.6	0.7	1.5
Screened out			
Boys	4.6†	5.4†	17.0
Girls	7.2†	4.0†	17.6
Flexibility test (sit-and-reach)			
Screened in			
Test completed			
Boys	97.2†	99.0	100.0
Girls	98.8	99.1	97.7*
Test not done			
Boys	2.5†	1.0	0.0
Girls	0.8	0.7	1.4
Screened out			
Boys	0.2	0.0	0.0
Girls	0.4	0.2	0.9
Muscular endurance (partial curl-ups)			
Screened in			
Test completed			
Boys	96.6†	95.9†	86.9
Girls	94.3†	96.1†	83.9
Test not done			
Boys	0.4	0.2	0.2
Girls	0.5	1.2	2.2
Screened out			
Boys	2.9†	3.8†	12.9
Girls	5.2†	2.7†	13.9
Muscular strength (grip strength)			
Screened in			
Test completed			
Boys	98.9	98.7	99.6
Girls	99.5	99.3	98.8
Test not done			
Boys	0.5	1.3	0.0
Girls	0.5	0.7	1.2
Screened out			
Boys	0.6	0.0	0.4
Girls	0.0	0.0	0.0

* significantly different from estimate for boys ($p<0.05$)
† significantly different from estimate for 15- to 19-year-olds ($p<0.05$)
[1] includes refusal, home interview and other reasons
[2] 6- and 7-year-olds excluded from estimates for aerobic fitness and muscular endurance (partial curl-ups)
Source: 2007-2009 Canadian Health Measures Survey

Table B
Percentage screened out of aerobic fitness tests, by sex and age group, household population aged 7 to 19 years, Canada, 1981 and 2007-2009

Sex and survey year	7 to 10 years	11 to 14 years	15 to 19 years
	%		
Boys			
1981	4.3	2.1	6.0
2007-2009	4.2	5.4	17.0*
Girls			
1981	3.0	3.2	9.9
2007-2009	7.0	4.0	17.6*

* significantly different from estimate for 1981 ($p<0.05$)
Sources: 1981 Canada Fitness Survey, 2007-2009 Canadian Health Measures Survey

Table C
Sample sizes for fitness assessments, by age group and sex, household population aged 6 to 19 years, Canada, March 2007 to February 2009

	6 to 10 (8 to 10) years[†]		11 to 14 years		15 to 19 years	
Fitness assessment	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**
Total sample	**450**	**420**	**318**	**302**	**288**	**309**
Total sample excluding 6- and 7-year-olds[†]	**283**	**259**	**318**	**302**	**288**	**309**
Total sample with score assigned for:						
Aerobic fitness (mCAFT)	215	209	283	272	242	241
Flexibility (sit-and-reach)	438	414	315	300	288	302
Muscular endurance (partial curl-ups)	271	246	305	289	260	261
Muscular strength (grip strength)	446	418	316	301	286	307
Total sample with measurements taken for:						
Body mass index	448	420	318	302	287	306
Waist circumference	449	420	317	301	288	306
Sum of five skinfolds[‡]	445	409	305	290	261	280

† 6- and 7-year-olds excluded from estimates for aerobic fitness and muscular endurance (partial curl-ups)
‡ excludes respondents with BMI 30.0 kg/m^2 or higher
Source: 2007-2009 Canadian Health Measures Survey